A QUANTITATIVE STUDY OF TRANSPIRATION

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(WITH TWO FIGURES AND THIRTY GRAPHS)

In the Laboratory of Plant Physiology of Smith College a systematic series of studies is being made to determine which of the plants available to American teachers are best for the demonstration, or investigation, of each of the principal physiological processes, and how much may be expected of them. Some of these studies in physiological constants have already been completed and others are well under way. I have undertaken to determine these facts for the process of transpiration. This work has been done under the direction of Professor W. F. GANONG, whose advice and supervision I gratefully acknowledge.

Transpiration has been extensively investigated from several points of view, and the results up to 1904 are all summarized in BURGERSTEIN's admirable monograph.[1] It shows that investigations have been directed mainly to explain the amounts of transpiration as depending either upon structural features or upon physiological processes, or as controlled by physical changes. Special work now being done by LIVINGSTON, LLOYD, and others at the Carnegie Desert Laboratory in Arizona is likely greatly to extend our knowledge of transpiration as an ecological factor in the plant life of the desert. But nothing has as yet been done in the direction of the present study. I have not been concerned with the explanation of transpiration upon either a physical or a physiological basis, nor yet with the relations between absolute and relative transpiration, but simply with the fact that plants lose appreciable amounts of water. I have sought to determine with precision the actual amounts of water lost by plants, growing under the ordinary conditions arising in any greenhouse, and simultaneously have determined the transpiration under conditions which admit of control and repetition.

My procedure was as follows. In each species studied, two well-grown plants, of as nearly the same size as could be found, were chosen at maturity, when increase of leaf surface is at a minimum.

[1] BURGERSTEIN, ALFRED, Die Transpiration der Pflanzen. Jena. 1904.

Two or three days before use, these were brought into the experimental greenhouse, where conditions of heat, moisture, and light were practically the same as in the greenhouse proper. Any plant likely to be pot-bound was repotted in the soil mixture for common plants two or three weeks before the test, in order that it might become properly adjusted.

The actual transpiration was determined throughout by the most accurate known method, that of weighing. To prevent evaporation

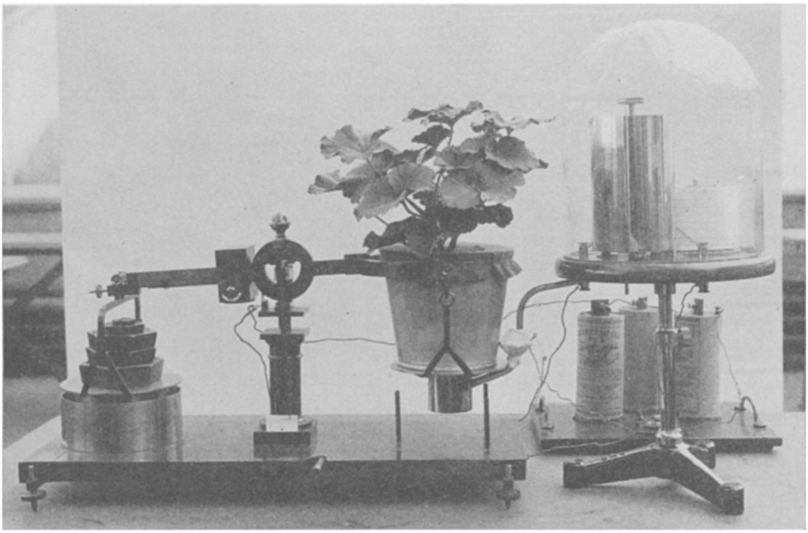


FIG. 1

from the pot and soil, each pot was covered by an aluminum or zinc shell of proper size, roofed over by rubber sheeting. This was tightly clasped to the plant, cemented along the seam, and fastened to the shell by a metal band, removable to permit the plant to be watered.

The plant to be kept under greenhouse conditions was then placed on a specially constructed balance which was brought into electrical connection with the autographic transpirometer invented by Professor GANONG and described by him in this journal.[2] The entire arrangement, slightly modified from the original form, is well shown

[2] GANONG, W. F., New precision appliances for use in plant physiology. BOT. GAZETTE 39:145. 1905.

in the accompanying *fig. 1*. By this apparatus the time and amount of transpiration are recorded continuously.

Each plant was under observation for six consecutive days (Monday morning to Saturday afternoon): climatic changes were recorded in the near vicinity by the thermograph, hygrograph, and barograph, but as changes of pressure have no appreciable effect on the transpiration the records are not given. There is no satisfactory instrument recording the varying intensities of light and darkness in a form permitting the construction of a graph. Therefore the changes of light were recorded from observation and were afterward reduced to a graph form by the following method.[3] CLEMENTS' table[4] of light intensities for the different sun altitudes (the angle of the sun's rays with a horizontal surface) for Lincoln, Neb. (41° N. lat.), was taken as a basis and changed to suit the latitude of Northampton (42° 19″ N.). Then, since the intensities for any hour of the day obtained from measurements on the celestial globe and graphically represented for a brilliant cloudless day form a parabola with greatest value at sun noon, it was possible to construct graphs showing full sunlight for each day of the year. For cloudy days the percentage of intensities was determined from the following arbitrary basis, the percentages being those of full sunlight for the given time.

Slight fleecy clouds and haze..................	90 per cent.
Heavy clouds alternating with blue sky.........	85 per cent.
Light open clouds, shadows cast...............	80 per cent.
Overcast, dark clouds, not rainy...............	60 per cent.
Overcast, with dark clouds and heavy rain......	50 per cent.
Overcast, with dark clouds and snow...........	40 per cent.

The second plant was intended partly as a check upon results obtained from the first, but especially as a standard exposed to conditions which admit of comparison of one kind with another, and which can be repeated by other students. This plant was placed in a large glass case (*fig. 2*) of some 652 liters capacity where conditions were partly controlled, and were registered by the thermograph and hygrograph. The temperature was kept within the range of 19–21° C. and the moisture between 45 and 55 per cent. of saturation. The tempera-

[3] For aid in the calculation of the light values I wish to thank Dr. HARRIET BIGELOW of the Astronomy Department.

[4] CLEMENTS, F. E., Research methods in ecology 57. 1905.

ture was raised by an electric heater in the bottom of the case, and lowered by a metal coil, cooled by water from the street pipes, in the top of the case. To promote prompt and even warming or cooling,

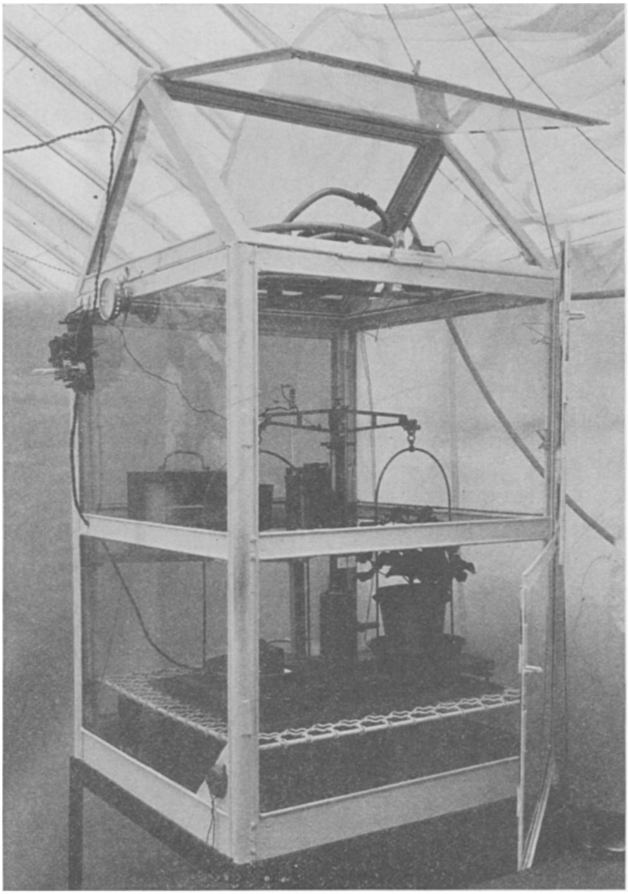


FIG. 2

electric fans of small size were made to blow air over the heating or cooling arrangements. Moisture was decreased by uncovering dishes of calcium chlorid and increased by exposing wet sponges and cloths. The case was always brought to the standard conditions, the plant was weighed and left in *still air* for as long a time as the conditions remained

within the prescribed limits; then it was weighed again, the results being reduced to an hour basis. The light was kept bright and diffuse by manipulation of a white curtain. The value of the light was considered about 90 per cent. of that received by the plant under ordinary conditions. At times when the sun did not cast a shadow both plants were exposed to the same intensity. To keep the plant under conditions of aeration as nearly normal as possible, the case was opened every morning (when the plant was watered) and the air blown out by a large electric fan.

To allow the transpiration of these plants to be compared with one another, and especially to permit the transpiration of different sizes and kinds to be compared, it was necessary to reduce their transpiration values to a common standard. For this I adopted the unit system of grams per hour per square meter of leaf surface, which for convenience may be designated the M^2HG standard. Leaf area was taken for one side only and petioles were ignored unless the blade extended along the edge, when an approximate value of half the petiole was added. This system has great advantages in convenience over one in which both leaf surfaces are estimated, or in which the stems and petioles are taken into account, and since in general in any given kind of plant the amount of petiole and stem surface must be approximately proportional to the leaf surface, no error is involved in a comparative study. In certain studies, involving structural relations, etc., the stem and petiole areas would have to be considered. The surface area was computed by tracing the leaves on homogeneous paper, and weighing them after they were cut out; this value was then reduced to a square meter of surface, by the familiar method, viz., from the determination of the weight of a known unit area of the paper. Photographs of the plants kept under ordinary greenhouse conditions were made, all upon the same scale and against the same background (ruled in square centimeters). These are reproduced with their respective curves below, with the exception of three, of which the plates were accidentally destroyed.

The results of the study I have endeavored to express in the ways which will render them most useful. First in importance are the exact figures, which are contained in the following table and are reduced to average per hour. In the plant under greenhouse condi-

Name of plant	Greenhouse conditions								
	Actual loss per hour				Area of plant	M^2HG			
	Min.	Average		Max.		Min.	Average		Max.
		Day	Night				Day	Night	
	(g)	(g)	(g)	(g)	(m^2)				
Abutilon striatum	.123	1.731	.210	3.5	.05463	2.25	31.680	3.839	64.06
Begonia argentea guttata	.123	1.861	.356	3.5	.07465	1.648	24.947	4.776	47.05
Cestrum elegans	.22	1.524	.565	3.09	.06383	3.445	23.864	8.846	48.387
Chrysanthemum frutescens	.91	9.903	2.069	18.5	.12849	7.082	77.069	16.099	143.98
Cineraria stellata	.5	4.084	1.233	8.5	.15866	3.15	25.740	7.770	53.57
Coleus Blumei (var.)	.43	2.470	.819	5.09	.12164	3.53	20.305	6.732	41.84
Cucurbita Pepo	.19	6.437	.774	13.	.12420	1.53	51.832	6.229	104.66
Euphorbia pulcherrima	.34	3.442	1.155	6.	.07372	4.61	46.680	15.674	81.38
Ficus elastica	.153	2.882	.502	4.33	.07070	2.16	40.760	7.100	61.24
Fuchsia speciosa	.45	5.526	1.128	11.	.09976	4.51	55.390	11.305	110.26
Hedera Helix	.08	1.656	.213	3.09	.07090	1.128	23.356	3.007	43.58
Helianthus annuus	.386	6.670	.974	13.	.05056	7.634	131.920	19.264	257.12
Heliotropium peruvianum	.83	4.355	1.441	9.	.13009	6.38	33.470	11.070	69.18
Impatiens Holstii	.21	.946	.280	5.	.02383	4.74	27.708	9.212	81.75
Ipomoea purpurea	.084	4.783	.434	8.5	.06665	1.26	71.755	6.508	127.53
Lupinus albus	.119	2.855	.344	5.	.03615	3.29	78.970	9.515	138.31
Lycopersicum esculentum	.18	8.085	.803	15.5	.10673	1.686	75.750	7.52	145.23
Pelargonium domesticum	.116	5.156	.497	12.5	.08657	1.339	59.558	5.738	144.39
Pelargonium peltatum	.169	3.600	.446	7.	.07065	2.392	50.919	6.312	99.08
Pelargonium zonale	.44	6.940	1.135	17.	.14794	2.97	46.910	7.672	114.91
Phaseolus vulgaris	.3	2.348	.623	6.5	.06878	4.36	34.133	9.059	94.58
Primula sinensis	.155	1.242	.375	2.77	.07452	2.799	16.670	5.029	37.17
Ricinus communis	.29	1.694	.563	5.	.06115	4.74	27.708	9.212	81.75
Salvia involucrata	.315	8.313	1.123	12.5	.13382	2.35	62.121	8.390	93.404
Senecio mikanioides	.21	3.126	.737	8.	.06309	3.328	49.540	11.680	126.78
Senecio Petasitis	.57	9.708	2.492	19.	.14581	3.909	66.579	17.093	130.306
Tradescantia zebrina	.105	.819	.166	1.45	.02610	4.023	31.402	6.341	55.56
Tropaeolum majus	.1	9.668	1.813	15.	.12801	7.81	75.520	14.159	117.17
Vicia Faba	.129	2.296	.258	4.67	.04117	3.13	55.760	6.26	113.43
Zea Mays	.195	5.560	.703	12.	.12655	1.541	43.931	5.553	94.824

Greenhouse conditions								Standard conditions						
…al loss per hour: Average …ay (g)	…al loss per hour: Average Night (g)	…al loss per hour: Max. (g)	Area of plant (m²)	M²HG Min.	M²HG Average Day	M²HG Average Night	M²HG Max.	Actual loss per hour: Min. (g)	Actual loss per hour: Average Day (g)	Actual loss per hour: Max. (g)	Area of plant (m²)	M²HG Min.	M²HG Average Day	M²HG Max.
731	.210	3.5	.05463	2.25	31.680	3.839	64.06	.36	1.334	2.4	.05002	7.19	26.669	47.98
861	.356	3.5	.07465	1.648	24.947	4.776	47.05	1.08	1.375	1.58	.07216	14.979	19.070	21.914
524	.565	3.09	.06383	3.445	23.864	8.846	48.387	1.	1.187	1.15	.07043	14.198	16.860	16.328
903	2.069	18.5	.12849	7.082	77.069	16.099	143.98	6.6	8.830	12.05	.12955	50.945	68.159	93.014
084	1.233	8.5	.15866	3.15	25.740	7.770	53.57	2.4	3.045	3.35	.11274	21.287	27.005	29.714
470	.819	5.09	.12164	3.53	20.305	6.732	41.84	1.33	2.335	3.05	.11068	12.197	21.096	27.586
437	.774	13.	.12420	1.53	51.832	6.229	104.66	1.33	3.112	4.48	.13860	9.595	22.455	32.32
442	1.155	6.	.07372	4.61	46.680	15.674	81.38	2.58	4.207	5.1	.07385	34.935	56.960	69.058
882	.502	4.33	.07070	2.16	40.760	7.100	61.24	.7	2.121	3.5	.08070	8.67	26.280	43.37
526	1.128	11.	.09976	4.51	55.390	11.305	110.26	2.8	4.517	6.7	.12323	22.72	36.650	54.36
656	.213	3.09	.07090	1.128	23.356	3.007	43.58	.3	1.077	2.25	.06308	4.755	17.073	35.669
670	.974	13.	.05056	7.634	131.920	19.264	257.12	2.6	3.136	5.08	.06275	41.43	49.976	80.956
355	1.441	9.	.13009	6.38	33.470	11.070	69.18	1.6	3.758	9.2	.14274	11.209	26.327	64.45
946	.280	5.	.02383	4.74	27.708	9.212	81.75	1.78	2.168	2.12	.06618	26.89	31.530	32.03
783	.434	8.5	.06665	1.26	71.755	6.508	127.53	.9	1.76	1.22	.07295	12.337	24.127	16.72
855	.344	5.	.03615	3.29	78.970	9.515	138.31	.81	2.399	3.58	.04033	20.084	59.484	88.83
085	.803	15.5	.10673	1.686	75.750	7.52	145.23	1.8	3.284	4.07	.11415	15.768	28.769	35.65
156	.497	12.5	.08657	1.339	59.558	5.738	144.39	1.05	3.380	5.4	.06856	15.315	49.299	78.76
600	.446	7.	.07065	2.392	50.919	6.312	99.08	1.9	2.640	3.65	.09415	20.18	28.104	38.76
940	1.135	17.	.14794	2.97	46.910	7.672	114.91	1.58	4.17	7.95	.14669	10.77	28.427	54.145
348	.623	6.5	.06878	4.36	34.133	9.059	94.58	.51	.816	1.05	.06956	7 33	11.74	15.094
242	.375	2.77	.07452	2.799	16.670	5.029	37.17	1.4	2.408	3.8	.09895	14.148	24.33	38.40
694	.563	5.	.06115	4.74	27.708	9.212	81.75	1.78	2.168	2.12	.06618	26.89	32.754	32.03
313	1.123	12.5	.13382	2.35	62.121	8.390	93.404	2.9	4.350	6.15	.12892	22.49	33.750	47.79
126	.737	8.	.06309	3.328	49.540	11.680	126.78	1.05	2.297	3.64	.06689	15.69	34.340	54.40
708	2.492	19.	.14581	3.909	66.579	17.093	130.306	4.35	5.363	6.65	.18227	23.865	29.420	36.484
819	.166	1.45	.02610	4.023	31.402	6.341	55.56	.19	.581	.93	.02840	6.69	20.471	32.746
668	1.813	15.	.12801	7.81	75.520	14.159	117.17	4.45	7.880	11.07	.15056	9.423	52.335	73.505
296	.258	4.67	.04117	3.13	55.760	6.26	113.43	1.3	3.440	4.95	.05030	25.785	68.389	98.409
560	.703	12.	.12655	1.541	43.931	5.553	94.824	.7	1.990	3.08	.10464	6.689	19.017	29.434

tions I have given this average loss for the day and night separately, and have added the extremes observed in order to show how widely the transpiration may vary in the same plant. In the plant under standard conditions similar results are given, though for day only.

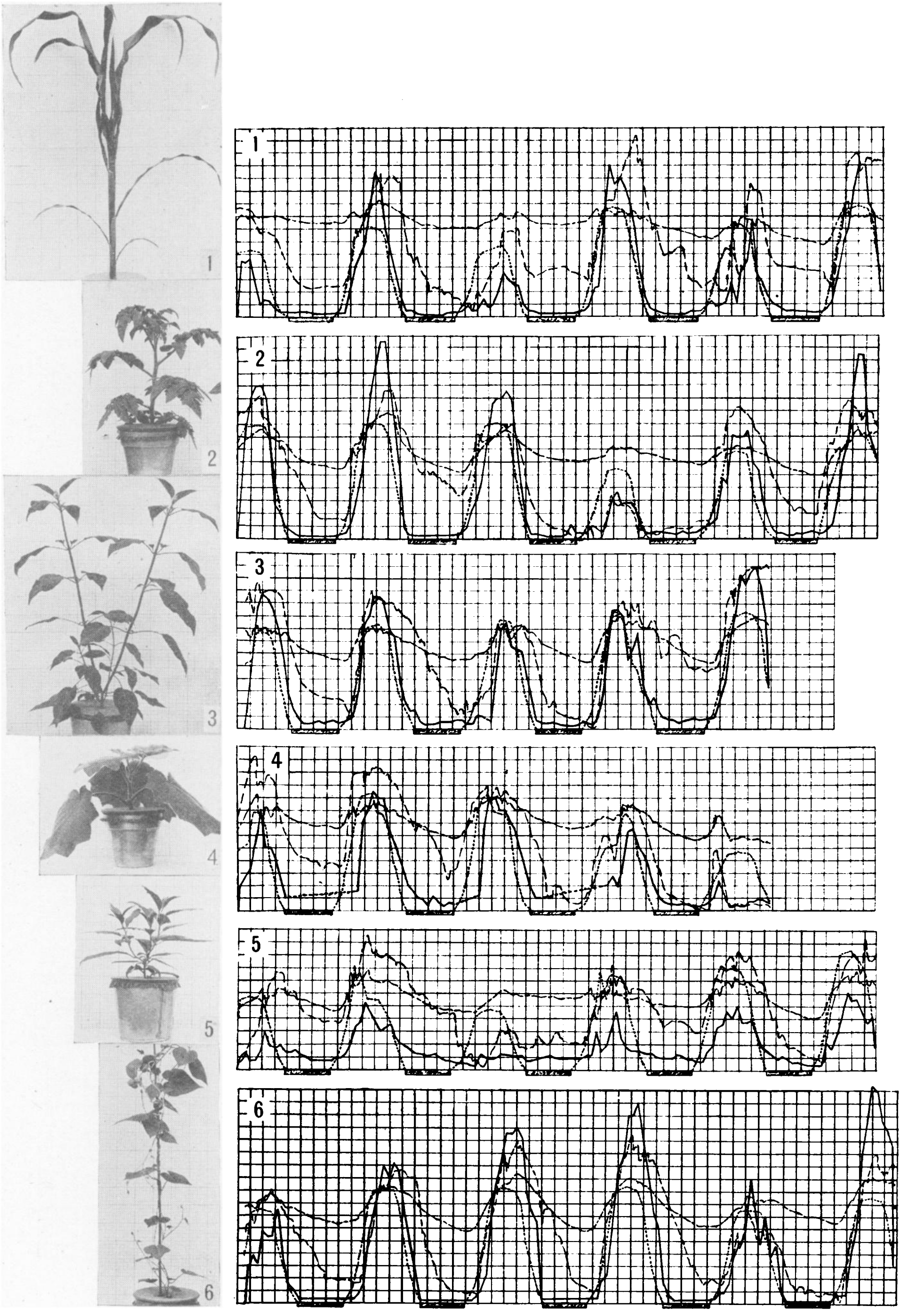
A comparison of the M^2HG figures for the ordinary and standard conditions of the same plant will reveal some remarkable discrepancies. Thus, Helianthus under the ordinary conditions stands far ahead of any other plants studied, but under the standard conditions it is surpassed by several. The explanation of such differences is evident. The week in which the experiment was tried may have been one of exceptional dryness and brightness, or one in which air currents from ventilation, or perhaps greater heat, increased the transpiration of the plant under ordinary conditions but could not materially affect that under standard conditions. It is evident therefore that for comparison of the transpiration of one plant with another the columns under ordinary conditions have little value, and for this the column under standard conditions should be used. It is in order to exhibit clearly the effects of such external conditions upon transpiration that I have plotted for the same plants the transpiration in graphs, along with the graphs of external conditions, in the series of diagrams which follow below. Another peculiarity of the tables is found in the great range in the same plant under standard conditions. This comes in part from the difficulty of keeping the conditions constant, in part from the great sensitiveness of the process to even slight alterations of external conditions, but chiefly from the variations in light. Absolute proof of this could only be obtained from a series of careful experiments where all factors would be under control and only one varied at a time. It can reasonably be inferred, however, on this ground: on bright sunny days there was a gradual increase and decrease proportional to the light intensity. On cloudy days or when the roof was covered with snow, with the curtain aside, the loss per hour varied within much narrower limits. Comparison of the losses at the same hours on different days also justifies this conclusion.

It will occur to the reader at this point that not enough plants of each species were used to give results which are fair tests of the transpiration of a given species. This criticism is only in part just. It is obviously impracticable to provide either the excessive time or the

numerous instruments requisite for obtaining averages from several plants. Aside from this, however, the results are more representative than may appear at first sight. On the one hand the plants were carefully chosen from a considerable number as typical specimens of their kinds, and on the other, according to QUÉTELET's law, any single plant taken at random is more likely to fall close to the mean than far from it. Hence, taking our thirty plants collectively, while some of them may deviate considerably from the mean of their kind, the great majority must lie more or less close to it.

Although the table of figures expressing the total quantities of transpiration has its value, it cannot be made to throw light upon the effect of external conditions upon transpiration. In consequence graphs made of each plant under *greenhouse conditions* were plotted from the records of the autographic instruments. In all cases they are for six days, the day and night being indicated on the base line. Each abscissa space represents $2\frac{1}{2}$ hours of time; each ordinate space in the transpiration curve equals either 1, $\frac{1}{2}$, or 2 grams of water lost, as indicated in each case, the difference being necessary to bring the curves of the plants within practical ranges; one vertical space in the temperature curve represents 5°; in the curve of moisture, 1 per cent. of saturation; and in that of light, 5, 2.5, or 10 per cent. of intensity. The curve of moisture has been inverted into one of dryness so that all physical conditions tending to increase transpiration have upward turns, and *vice versa*. The curve of light shows the intensities available to the plant, not what the plant actually used; this varies with the structure and the internal physiological processes.

As indicated above, these graphs have two values. The first is to show under what external conditions the figures for ordinary conditions given in the table were obtained. It is obvious that these values are profoundly affected by the conditions prevailing when the experiment was in progress. The second value is to present as clearly and graphically as possible the relations of the rate of transpiration to external conditions. It is not supposed that these graphs can bring out any knowledge of transpiration new in the abstract, but they do show this relation with gratifying clearness for our most familiar plants, and in a form which, it is hoped, will make them valuable in educational work.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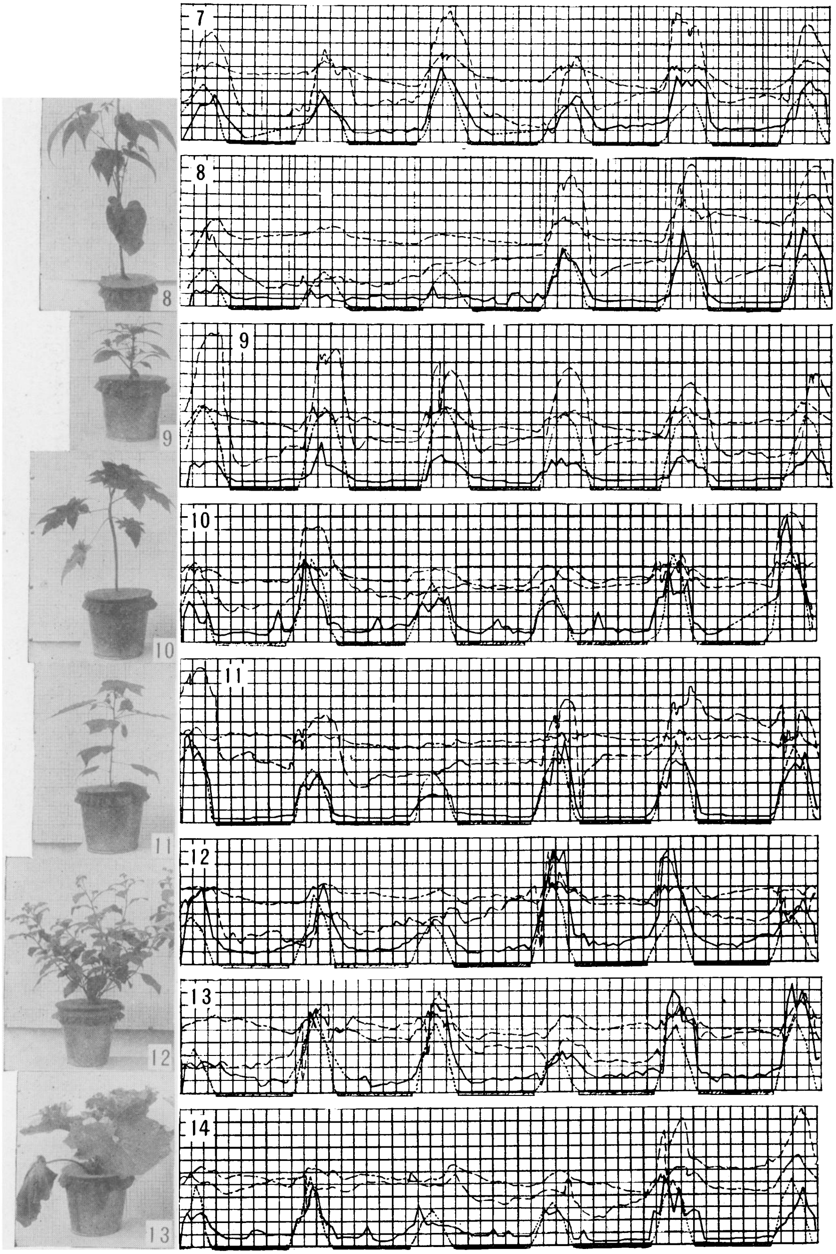
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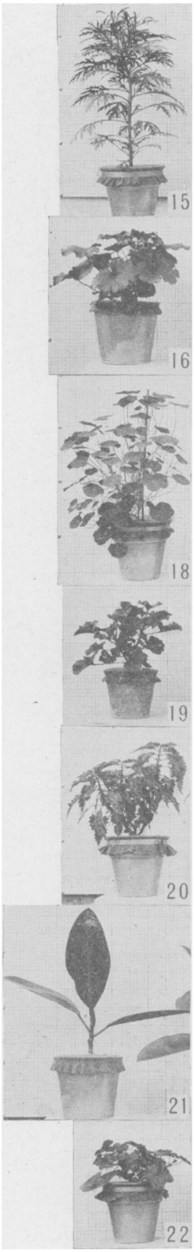
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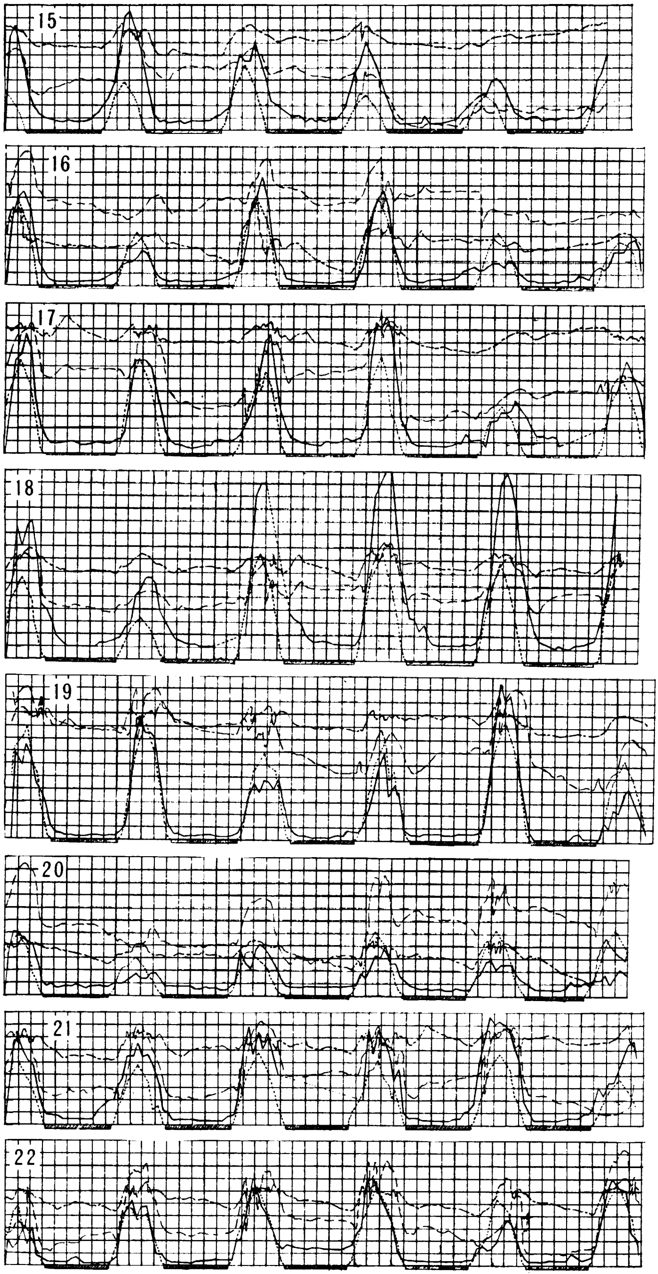
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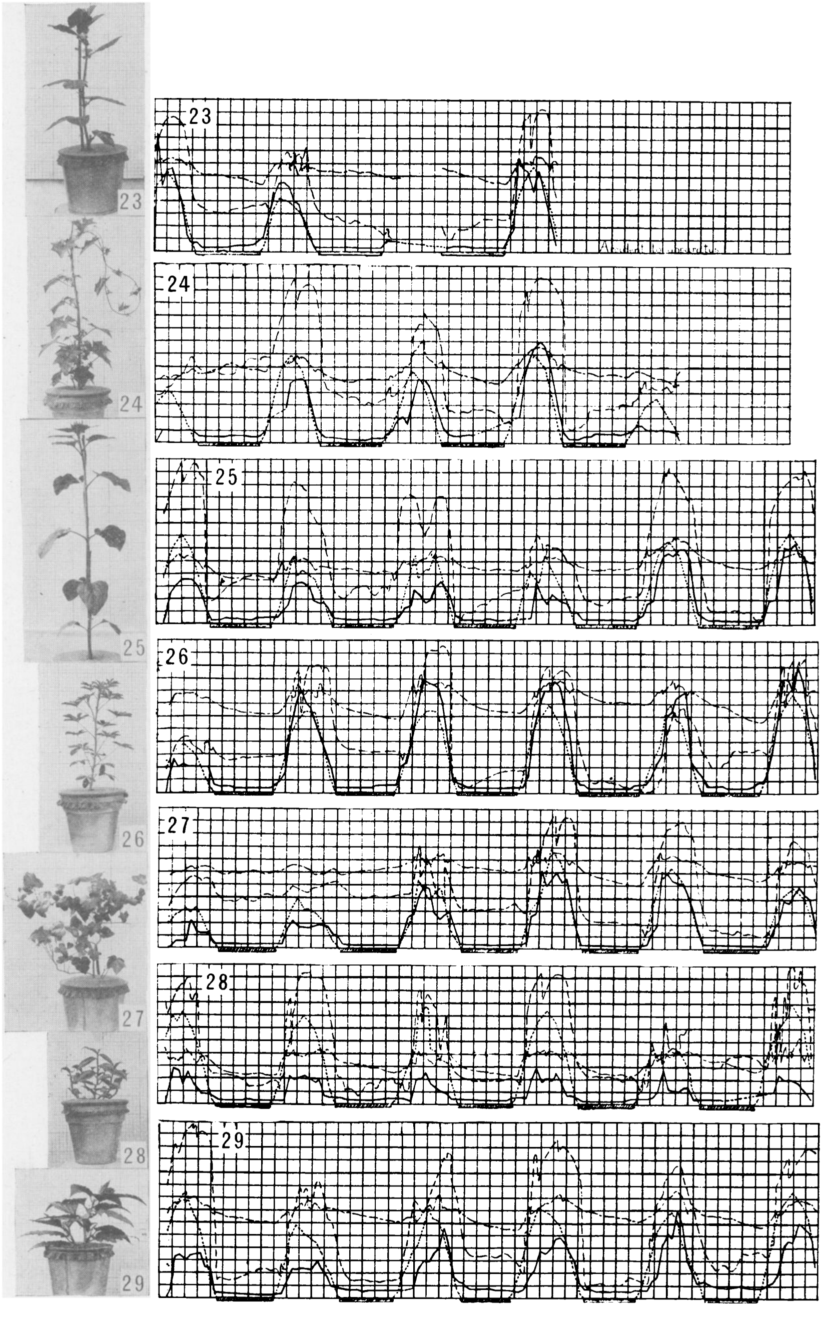
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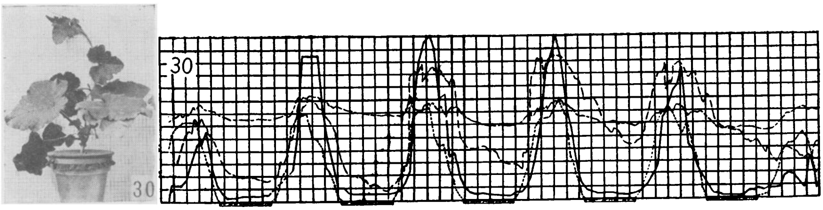

EXPLANATION OF GRAPHS

T = temperature — · · — · · — D = dryness — — — —
L = light · · · · · · · · Tr = transpiration ————————
The values given for *T* should be read in the seventh vertical space from the base line; *D* in the fifth; *L* in the third; and *Tr* in the first.

1. *Zea Mays.* May 7–12. T 10–15; D 30–35; L 20–30; Tr 0–1.
2. *Lycopersicum esculentum.* May 13–18. T 15–20; D 30–35; L 20–30; Tr 0–1.
3. *Salvia involucrata.* May 20–25. T 10–15; D 35–40; L 20–30; Tr 0–1.
4. *Senecio Petasitis.* May 28—June 2. T 10–15; D 35–40; L 20–30; Tr 0–2.
5. *Cestrum elegans.* June 3–8. T 20–25; D 35–40; L 20–30; Tr 0–½.
6. *Ipomoea purpurea.* June 10–15. T 10–15; D 30–35; L 20–30; Tr 0–½.
7. *Euphorbia pulcherrima.* Oct. 22–27. T 20–25; D 30–35; L 20–30; Tr 0–1.
8. *Phaseolus vulgaris.* Oct. 29—Nov. 3. T 15–20; D 40–45; L 20–30; Tr 0–1.
9. *Impatiens Holstii.* Nov. 5–10. T 20–25; D 40–45; L 10–15; Tr 0–½.
10. *Ricinus communis.* Nov. 12–17. T 20–25; D 40–45; L 10–15; Tr 0–½.
11. *Abutilon striatum.* Nov. 19–24. T 15–20; D 30–35; L 10–15; Tr 0–½.
12. *Heliotropium peruvianum.* Nov. 26–31. T 20–25; D 40–45; L 10–15; Tr 0–1.
13. *Cineraria stellata.* Dec. 6–12. T 20–25; D 50–55; L 10–15; Tr 0–1.
14. *Primula sinensis.* Dec. 13–19. T 20–25; D 40–45; L 10–15; Tr 0–½.
15. *Chrysanthemum frutescens.* Jan. 14–19. T 10–15; D 50–55; L 10–15; Tr 0–2.
16. *Pelargonium zonale.* Jan. 21–26. T 30–35; D 40–45; L 10–15; Tr 0–2.
17. *Fuchsia speciosa.* Jan. 28—Feb. 2. T 0–5; D 40–45; L 10–15; Tr 0–1.
18. *Tropaeolum majus.* Feb. 4–9. T 10–15; D 45–50; L 10–15; Tr 0–1.
19. *Pelargonium domesticum.* Feb. 11–16. T 0–5; D 30–35; L 10–15; Tr 0–1.
20. *Coleus Blumei* var. Feb. 18–23. T 50–55; D 20–25; L 20–30; Tr 0–1.
21. *Ficus elastica.* Feb. 25—Mar. 2. T 15–20; D 55–60; L 20–30; Tr 0–½.
22. *Pelargonium peltatum.* Mar. 4–9. T 20–25; D 50–55; L 20–30; Tr 0–1.
23. *Vicia Faba.* Mar. 11–20. T 15–20; D 40–45; L 20–30; Tr 0–½.
24. *Senecio mikanioides.* Mar. 18–23. T 20–25; D 30–35; L 10–15; Tr 0–1.
25. *Helianthus annuus.* Mar. 25–30. T 25–30; D 35–40; L 20–30; Tr 0–2.
26. *Lupinus albus.* Apr. 1–6. T 10–15; D 40–45; L 20–30; Tr 0–½.
27. *Hedera Helix.* Apr. 8–13. T 15–20; D 40–45; L 20–30; Tr 0–½.
28. *Tradescantia zebrina.* Apr. 15–20. T 30–35; D 40–45; L 20–30; Tr 0–½.
29. *Begonia argentea guttata.* Apr. 22–27. T 30–35; 15–20; DL 20–30; Tr 0–½.
30. *Cucurbita Pepo.* Apr. 29—May 4. T 15–20; D 30–35; L 20–30; Tr 0–1.

Briefly they bring out these facts: there are two daily extremes, a maximum loss around noon when the sunlight is most intense, heat usually the greatest, moisture least in the atmosphere, but a good supply of water in the soil around the roots; the minimum loss occurs some time during the night when the temperature is low, the atmospheric moisture approaches saturation, the darkness is complete, and in most plants the stomata are closed. The curve from 8 to 9 in the morning sometimes suddenly drops or rises. This is due either to the

time lost when the plant is watered and rebalanced or to the falling of sunshine directly upon the plant. The drop in the curves between February and March 18 just after noon is due to the shading of the plant from the direct afternoon sun by an intervening house.

The effects of cool, cloudy, moist days are well brought out in the curve of *Phaseolus vulgaris*, where such conditions prevailed the first half of the week, tending to check transpiration; while the brighter, warmer, drier, latter half of the week increased the loss of water. The same differences are seen equally well in the curves of *Pelargonium domesticum* and *P. peltatum*, Fuchsia, and Tropaeolum; and are more strikingly shown in those of *Senecio mikanioides*, *Lupinus albus*, *Zea Mays*, *Senecio Petasitis*, *Cucurbita Pepo*, *Lycopersicum esculentum*, and *Abutilon striatum;* but the last-named plant and Chrysanthemum were at no time in brilliant sunlight.

In general the transpiration curve supplements the tabulated results, showing in addition the effects of physical conditions. The important fact brought out by the curves as a whole is the extreme sensitiveness of transpiration to even slight changes in external conditions, a fact already mentioned above in connection with the variations shown under "standard" conditions. So great, indeed, is this sensitiveness that it seems out of all proportion to the direct physical changes and suggests the possibility that the relation between conditions and transpiration is not purely physical, as it is apparently now considered by some students, but is indeed one which involves the action of the conditions as stimuli. But this is a separate matter and I have been concerned merely with transpiration as a fact, quite regardless of its explanation. Furthermore, I have not tried to separate the influence of the conditions nor to show, when several cooperate, which produces the greatest effect. I have taken them as they came; their separation is a separate investigation.

We consider now the results of this study from the practical point of view of the teacher, as to which plants are best for the demonstration of transpiration. While the columns designated "M^2HG average" give some plants a greater average transpiration, the columns of "M^2HG minimum and maximum" really offer a better choice of material, because they show the great range possible for each plant. *Helianthus annuus* stands first in amount of transpiration, but it is open

to objection in that it is not kept in greenhouses and must be grown expressly several weeks before needed for use in the classroom. *Vicia Faba*, *Lupinus albus*, *Lycopersicum esculentum*, *Ipomoea purpurea*, and *Cucurbita Pepo*, although they show a high rate of transpiration, are open to the same objection. The first choice falls, then, in order of respective excellence to *Chrysanthemum frutescens*, *Tropaeolum majus*, *Pelargonium domesticum*, *Fuchsia speciosa*, *Senecio Petasitis*, *Senecio mikanioides*, *Pelargonium zonale*, *Heliotropium peruvianum*, and *Pelargonium peltatum*. They are best for two reasons: their first value lies in the fact that they lose large amounts of water; the second, and no less important, is that in addition to their being easily obtained at any time of year from the greenhouse, they are grown in many homes. An objection to *Euphorbia pulcherrima* and *Impatiens Holstii*, moderate transpirers, is that they lose many leaves just at maturity; this is true also of the heliotrope. Of least value are *Primula sinensis*, *Coleus Blumei*, *Hedera Helix*, *Cestrum elegans*, *Begonia argentea*, and *Tradescantia zebrina*, which, though common, have a very low rate of transpiration.

In addition to the value given by the tables for the different kinds of plants, it will be of some interest to note the average transpiration for these plants taken collectively. The result may be considered a general expression of the amount of transpiration of ordinary plants growing in any greenhouse. This quantity is 48.732 or in round numbers about 50 grams per hour per square meter of surface for the day time, and 8.898, or in round numbers 10 grams for the night—about five times as much on the average per hour per square meter by day as by night.

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